

# EXPANSION OF THE EXOTIC AQUATIC PLANT *CRYPTOCORYNE BECKETTII* (ARACEAE) IN THE SAN MARCOS RIVER, TEXAS

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## ABSTRACT

*Cryptocoryne beckettii* Thw. ex R. Trim. is an exotic aquatic plant recently found in the San Marcos River, Texas. The species is currently expanding rapidly within the lower portions of the upper San Marcos River. The distribution and areal extent of the species was quantified on three occasions between April 1998 and August 2000. During this 28-month period, the number of individual colonies increased from 11 to 63, and the total areal coverage increased from 171 to 646 m<sup>2</sup>. The average rate of areal expansion during this period was 80% per year. Most colonies of *C. beckettii* were found to be small (< 5 m<sup>2</sup>), although in August 2000 three colonies were greater than 50 m<sup>2</sup> in size. All colonies were found at water depths between 30 and 120 cm and appeared to favor more rapidly flowing water. This preference for shallow, rapidly flowing areas of the river makes *C. beckettii* a potentially serious threat to *Zizania texana* Hitchc., an endangered plant endemic to the San Marcos River, that occupies a similar river zone. All known colonies of *C. beckettii* are currently downstream from the remaining stands of *Z. texana*.

## RESUMEN

*Cryptocoryne beckettii* Thw. ex R. Trim. es una planta acuática exótica encontrada recientemente en el río San Marcos, Texas. La especie está actualmente expandiéndose rápidamente por las partes bajas de la cuenca alta del San Marcos. La distribución y área de extensión de la especie fue cuantificada en tres ocasiones entre abril de 1998 y agosto de 2000. Durante este periodo de 28 meses, en número de colonias individuales se incrementó de 11 a 63, y el área total de recubrimiento se incrementó de 171 a 646 m<sup>2</sup>. La tasa media de expansión del área durante este periodo fue del 80% por año. La mayoría de las colonias de *C. beckettii* son pequeñas (< 5 m<sup>2</sup>), aunque en agosto de 2000 tres colonias eran mayores de 50 m<sup>2</sup>. Todas las colonias se encontraron en profundidades de agua entre 30 y 120 cm y parecían favorecer un flujo de agua más rápido. Esta preferencia por las áreas del río poco profundas y con flujo rápido hace de *C. beckettii* una amenaza potencial seria para *Zizania texana* Hitchc., una planta endémica amenazada del río San Marcos, que ocupa una zona fluvial similar. Todas las colonias conocidas de *C. beckettii* están actualmente aguas abajo de las posiciones restantes de *Z. texana*.

## INTRODUCTION

The San Marcos River, Hays County, Texas, originates from a series of springs along the San Marcos Springs fault within the city of San Marcos, Texas. The river flows 130 km to its confluence with the Guadalupe River near the city of Gonzales. The upper river, defined as the eight km between its origin and its

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confluence with the Blanco River, is the subject of substantial interest due to the presence of several endangered species (USFWS 1996). The river maintains relatively constant temperature and water chemistry year around, and this constancy may be responsible for the biological uniqueness of the system (Hannan & Dorris 1970; Lemke 1989; Groeger et al. 1997). This river supports the greatest known diversity of aquatic organisms in Texas, and several of the more rare species are limited to the upper portion of the river (Staton 1992; USFWS 1996). Considered an ecologically sensitive and critical habitat by the US Fish and Wildlife Service (USFWS 1996), the upper river harbors several endangered aquatic species, including *Zizania texana* Hitchc. (Texas wild rice), *Typhlomolge rathbuni* Stejner. (San Marcos blind salamander), and *Etheostoma fonticola* Jordan & Gilbert. (fountain darter), and the threatened *Eurycea nana* Bishop. (San Marcos salamander). *Gambusia georgei* Hubbs & Penden. (San Marcos gambusia) is a fish species thought to have recently gone extinct from the San Marcos River.

The river's spring-fed waters provide excellent habitat for the luxuriant growth of numerous more common aquatic plant species as well. Lemke (1989) reported the presence of 27 species of aquatic flowering plants as well as two species of aquatic ferns and two aquatic bryophytes. Unfortunately, eight of these species are exotic to the United States including some that are known to spread aggressively. The most abundant plant found in the upper river is now the notorious *Hydrilla verticillata* (L.f.) Royle, a non-native plant known to cause substantial management and ecological problems (see Langeland 1996). Another introduced aquatic plant species here is *Hygrophila polysperma* (Roxb) T. Anderson, native of India and Malaysia. Angerstein and Lemke (1994) hypothesized that the high growth potential of *H. polysperma* also poses a serious threat to the native flora and the biotic integrity of the San Marcos ecosystem. Although there is little historic information on the distribution of *H. polysperma* during the 25 or so years it has been in the system, it appears to have expanded dramatically during the last 15 years. In his survey of the upper river, Lemke (1989) categorized *H. polysperma* (although misidentified as *Hygrophila lacustris* (Schlecht. & Cham.) Nees as "uncommon" which he defined as "restricted to one or a few locations in the study area." Today, this species is widespread in the upper river and second only to *H. verticillata* in abundance (Doyle, unpublished data). *Hygrophila polysperma* appears able to compete with *H. verticillata* (Les and Wunderling 1981) and apparently can easily outcompete *Ludwigia repens* Forst., a native aquatic macrophyte which has a similar growth form (Francis 2000). One other exotic aquatic plant species known to inflict damage on native flora is *Myriophyllum spicatum* L. (see Madsen et al. 1991) a species found abundantly in Spring Lake at the headwaters of the San Marcos River, although only rarely in the river itself.

Recently, a new exotic aquatic plant species identified as *Cryptocoryne beckettii* Thw.ex R.Trim. was found in the San Marcos River (Rosen 2000). The



identification provided by Rosen (2000) was based only on vegetative characteristics, but more recent observations of floral characteristics from a sample collected from the river and grown in quarantine culture appear to confirm this species identification (Ken Saunders, Texas Parks and Wildlife Department (TPWD), personal communication). In this paper, I report information on the distribution and recent expansion of this species within the San Marcos River based on three vegetation assessments conducted between April 1998 and August 2000.

#### METHODS

The distribution and abundance of *C. beckettii* in the San Marcos were assessed in 1998, 1999, and 2000 as part of a larger vegetation assessment of the flora of the entire river. The specific survey dates (with river flow rates for those dates in parentheses) were: April 02, 1998 (6.20 cms); August 27, 1999 (3.88 cms); and August 25, 2000 (3.42 cms).

For each colony seen, its geographic location and the colony size were recorded using a high-resolution GPS unit (Trimble Pro XR), which was set to record data only where spatial resolution was considered "excellent" ( $\pm 70$ - to 100-cm point resolution). Colonies larger than approximately 16 m<sup>2</sup> were mapped by circumnavigating each colony with the GPS unit. Water depth was also measured, using a standard depth pole depth gauge. For the larger colonies, the depth recorded was the depth considered to be most representative of the overall colony. Smaller colonies were mapped by recording a GPS point in the geographic center of a colony and recording North/South and East/West dimensions. Water depth was recorded where the GPS point was taken. In sections of the river where water was deeper and without a clear view of the bottom ( $> 1.7$  m), I searched for *C. beckettii* by dragging a heavily weighted plant rake attached to a rope. Although not quantitative, this sampling technique is effective in determining presence/absence of submersed aquatic plants. *Cryptocoryne beckettii* was not found in any of the deeper portions of the river.

In 1998 and again in 2000 vegetative voucher specimens were collected from the river. I have not observed the species in flower in the river.

Flow velocities were taken in March 2001 at two of the larger colonies located near the upper end of Reach 12, using a Marsh-McBirney (Flo-Mate Model 2000). The measurements were taken just above the plant canopy (ca. 20 cm off the bottom).

#### RESULTS

##### **Location of colonies, August 2000**

*Cryptocoryne beckettii* has only been observed in the lower portions of the upper San Marcos River (Fig. 1). In August 2000, the most upstream colony was located just below the "power line." That location, named for the high-voltage



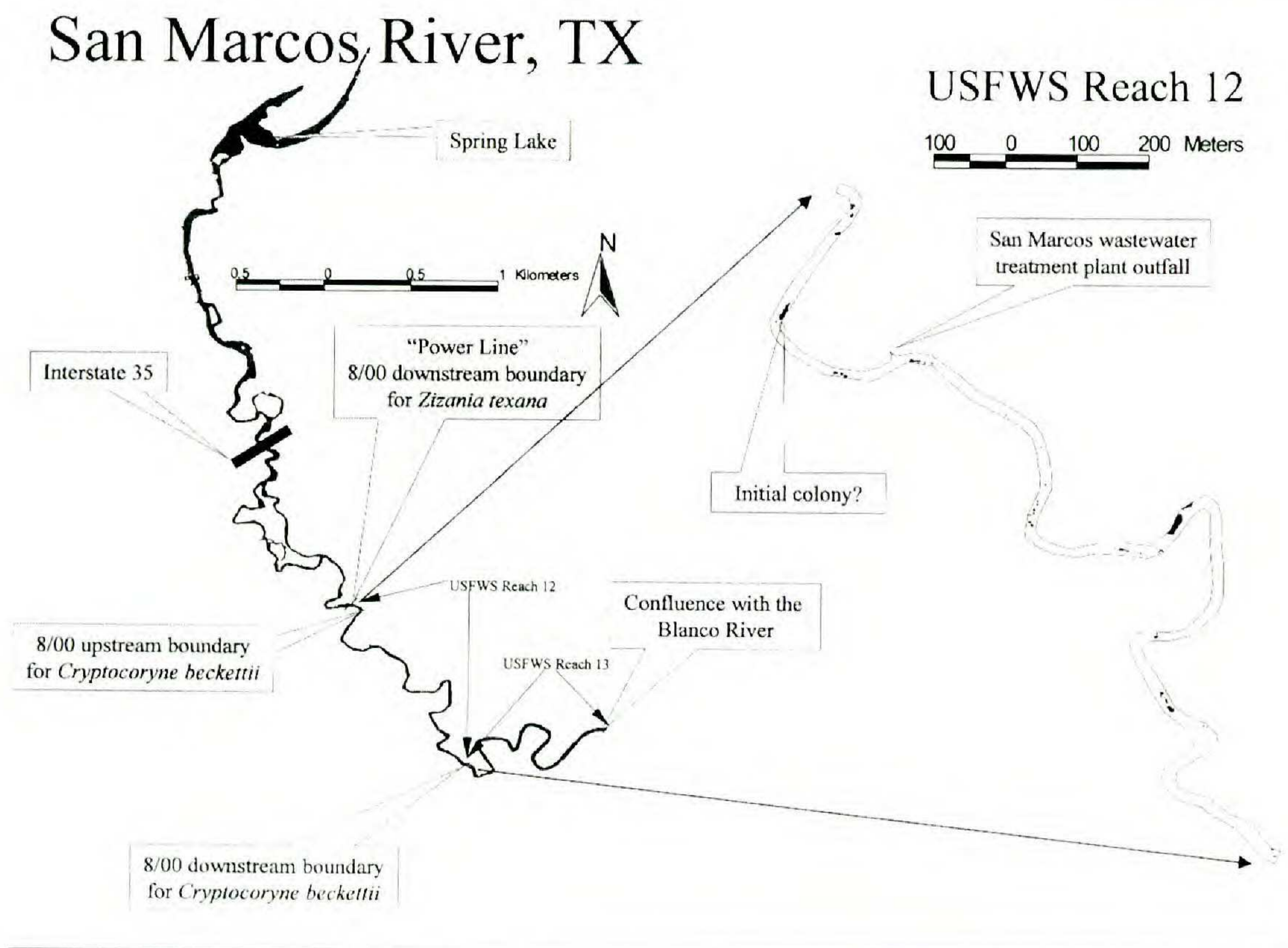


FIG. 1. Distribution of *Cryptocoryne beckettii* in the San Marcos River, Hays County, Texas, U.S.A. on August 25, 2000.

power line that crosses the river, is the beginning of the USFWS monitoring Reach 12. This colony was located about 20 m downstream of the southernmost stand of *Z. texana*, which is just upstream of the power line crossing. *Cryptocoryne beckettii* was widely distributed throughout Reach 12 and was the dominant aquatic macrophyte in that Reach (Table 1). Unlike most of the river, Reaches 12 and 13 are largely shaded by riparian tree canopy and are very sparsely populated by aquatic macrophytes. Total coverage by aquatic macrophytes in these sections is only about 3.6% of the total Reach area, and *C. beckettii* accounted for 73% of all aquatic vegetation coverage in that area.

Only four tiny colonies of *C. beckettii* totaling 1.0 m<sup>2</sup> were found in Reach 13. These were located just downstream of the division between Reaches 12 and 13.

#### Water depth and size of colonies, August 2000

In August 2000, most *C. beckettii* colonies were located at depths of 30 to 90 cm (Fig. 2). No colonies were located in water shallower than 30 cm nor in water deeper than 120 cm. Although 27% of all colonies were located in water deeper than 90 cm, these colonies tended to be small, so the areal coverage in deeper water was only about 13% of the total areal coverage. Because the August 2000 survey was conducted at relatively low river flow (3.42 cms), I believe all colonies surveyed remain completely submersed throughout the year.



TABLE 1. Abundance of all aquatic plant species in USFWS Reaches 12 and 13 of the San Marcos River, TX, in Oct 2000. Species are identified as exotic (E) or native (N).

Species	Total Area (m <sup>2</sup> )	Number of colonies
REACH 12		
<i>Cryptocoryne beckettii</i> (E)	644.5	59
<i>Heteranthera dubia</i> * (N)	7.9	9
<i>Hydrilla verticillata</i> (E)	11.3	8
<i>Hygrophila polysperma</i> (E)	197.9	29
<i>Justicia americana</i> (N)	4.3	3
<i>Nuphar luteum</i> (N)	5.5	4
<i>Sagittaria platyphylla</i> (N)	<0.1	1
<i>Vallisneria americana</i> (N)	9.5	2
<i>Zosterella dubia</i> * (N)	7.9	9
REACH 13		
<i>Cryptocoryne beckettii</i> (E)	1.0	4
<i>Hygrophila polysperma</i> (E)	7.25	12
<i>Nuphar luteum</i> (N)	42.4	7

\**Zosterella dubia* = *Heteranthera dubia* = *Heteranthera liebmannii*

Most *C. beckettii* colonies in the San Marcos River were small in August 2000. Of the 63 discreet colonies identified, 42 were < 5 m<sup>2</sup>. At the same time 48% of the total population occurred in only three colonies, which ranged in size from 53 to 160 m<sup>2</sup>.

**Expansion of colonies over three years, 1998–2000**

In all three surveys, the majority of all colonies were less than 5 m<sup>2</sup> in size, and relatively few colonies were greater than 10 m<sup>2</sup> (Fig. 3A). However, between 1998–2000 the absolute number of colonies in each size class increased (Fig. 3B) indicating that the population continued to expand and that individual colonies were continuing to grow in size.

The number of colonies and the area covered by *C. beckettii* increased significantly during the survey period (Fig. 4). In April 1998 there were only 11 colonies of *C. beckettii*, and 68% of the total areal coverage was found in one large colony located in the shallows on the inside of a bend in the river just above the wastewater treatment plant (Fig. 1). The total number of colonies between April 1998 and August 2000 increased from 11 to 63 (Fig. 4A), while total areal coverage of the species increased from 171 m<sup>2</sup> to 646 m<sup>2</sup> (Fig. 4B). The rate of increase in areal coverage averaged about 80% per year.

**Flow velocity over *Cryptocoryne beckettii* colonies**

In March 2001, the flow over two large *C. beckettii* colonies was 0.56 and 0.75 m s<sup>-1</sup>. These colonies were located near the upstream limits of the population, but appeared visually similar to most of those observed within the river.



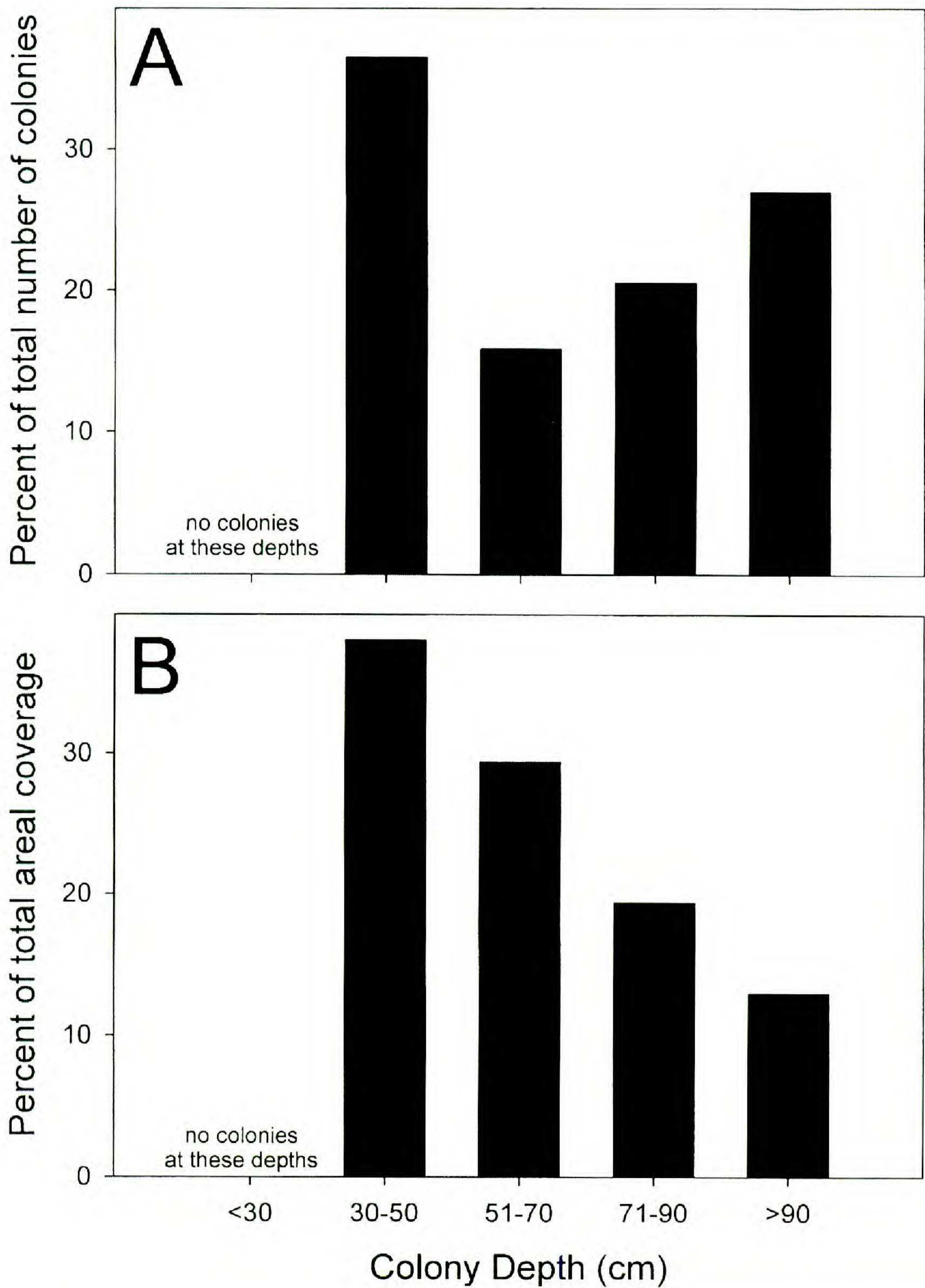


FIG. 2. Distribution of *Cryptocoryne beckettii* at measured water depths. (A) Frequency of colonies at different depths. (B) Frequency of percent of total areal coverage at different depths. Measurements taken on August 25, 2000 in the San Marcos River, Hays County, Texas, U.S.A.



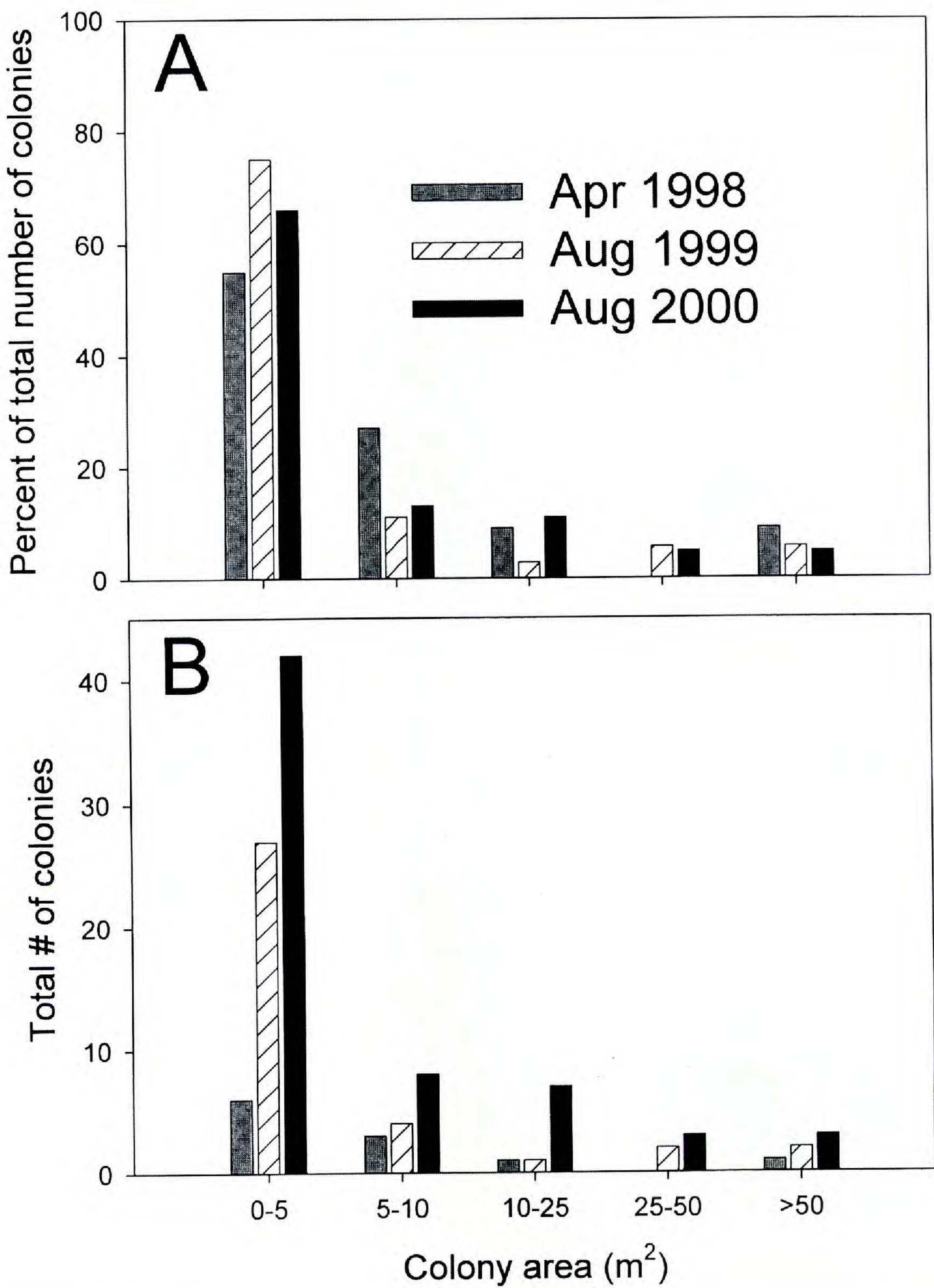


FIG. 3. Distribution of *Cryptocoryne beckettii* colonies in the San Marcos River, Texas, by size classes. (A) Percent of colonies in each size class. (B) Number of colonies in each size class.



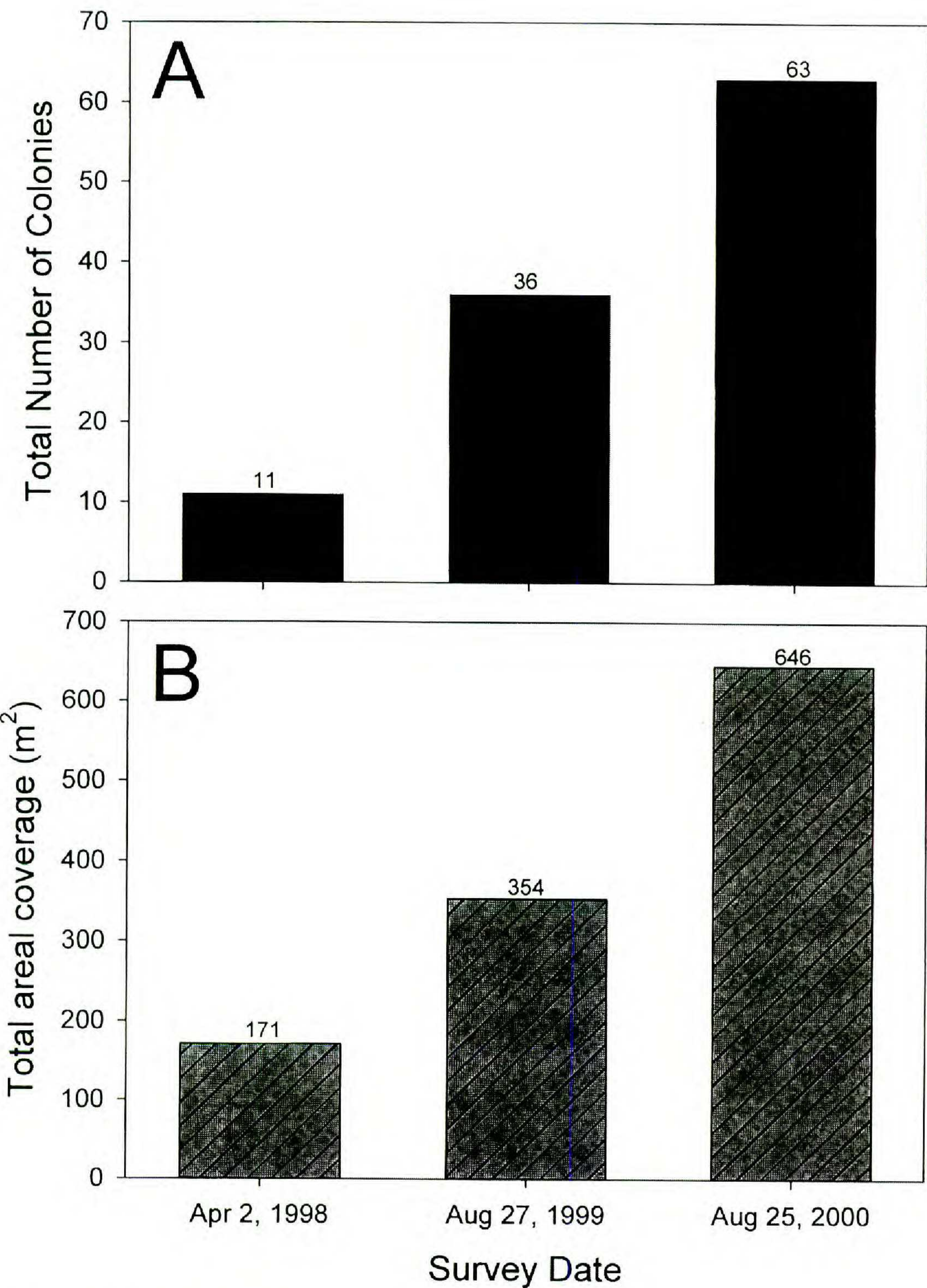


FIG. 4. Number of colonies (A) and total areal coverage (B) of *Cryptocoryne beckettii* in the San Marcos River, Texas, 1998–2000. Exact number of colonies or total areal coverage is given above the bar for each sampling period.



## DISCUSSION

Many introduced aquatic plant species have spread beyond their native ranges, and some problematic weeds have expanded in spectacular fashion in their new habitat (Cook 1990). These alien species may interact with the native flora in various ways (Falinski 1998), such as filling a long-empty ecological niche in the community (supplementary interaction), filling a recently vacated niche (compensatory), or displacing one or more native species with similar biological and ecological requirements from a filled niche (substitutive). Although reliable criteria to determine accurately the ultimate weed potential of new invaders have not been developed (Mack 1996; Zamora et al. 1989), species that are likely to interact with native flora in negative ways should be considered to have high noxious weed potential (Bazzaz 1986).

**Expansion of *Cryptocoryne beckettii***

During the survey period, *C. beckettii* increased at an alarmingly rapid rate. Between April 1998 and August 1999, *C. beckettii* areal coverage expanded at an annual rate of 80.2%. Between August 1999 and August 2000, the areal coverage of the population increased by 82.5%. Although the rate of expansion is likely to slow as the most suitable habitats become colonized, at the current average rate of expansion (80% per year) *C. beckettii* could cover 100% of Reach 12 in less than five years.

**Potential threat to *Zizania texana***

The morphology of *Z. texana* and *C. beckettii* differ substantially. *Zizania texana* is characterized by long, ribbon-like leaves often observed to be 1–2 m in length (Terrell et al. 1978) while the ovate leaves of *C. beckettii* are typically only 15–30 cm in length, including both petiole and blade. Even so, I believe the introduction of *C. beckettii* into the San Marcos ecosystem may pose a substantial threat to *Z. texana*, because the two species appear to have similar depth and flow preferences. Poole and Bowles (1999) surveyed 44 individual stands of *Z. texana* in August 1994 and found that the water depth for these stands averaged  $0.75 \pm 0.16$  m (95% c.i.). In August 2000, the 63 surveyed colonies of *C. beckettii* were in an average water depth of  $0.72 \pm 0.07$  m (95% c.i.), indicating that the two species occupy virtually identical depth zones within the river. Furthermore, both species appear to favor locations with relatively high current velocity. Poole and Bowles (1999) further reported that the 44 stands of *Z. texana* had an average current velocity of  $0.56 (\pm 0.20)$  m s<sup>-1</sup> (95% c.i.). Although current velocity near *C. beckettii* was measured only once and at only two colonies, the observed velocity range of 0.56 to 0.75 m s<sup>-1</sup> indicates that this exotic species occupies a flow environment very similar to that of *Z. texana*.

One major habitat difference between the two species may indicate a difference in the degree of shading that can be tolerated. *Zizania texana* is most frequently found in full sun, while, at present, *C. beckettii* is found predomi-



nantly in more heavily shaded regions of the river. However, historical, unpublished data from TPWD indicate that within the past five years there have been stands of *Z. texana* extending farther downstream than the current distribution into sections of the river now dominated by *C. beckettii*.

The fact that *C. beckettii* may have similar habitat preferences to *Z. texana* does not indicate that it can or will displace remaining stands of the native plant. In fact, it is possible that established *Z. texana* stands, like other established native species such as *Vallisneria americana* Michx. will be a very effective competitor against an invading alien species (see Smart et al. 1994). However, given that the distribution of *Z. texana* is currently much reduced from historic levels (USFWS 1996), an aggressively expanding alien species such as *C. beckettii* may quickly occupy habitat that might otherwise be re-colonized by *Z. texana*.

### **Management recommendation**

Eradication is ultimately the most desirable response to a new plant invasion, especially when it appears likely to interfere with an important native species. However, this outcome is most likely when plant populations are relatively small and contained; large or widely distributed populations require considerably more knowledge, money, and effort to achieve eradication (Coblentz 1990; Zamora & Thill 1999). The current abundance and distributional pattern of *C. beckettii* appears to lend itself to implementing an eradication effort. In August 2000, the population of *C. beckettii* was relatively small (646 m<sup>2</sup>) and limited to a 1.7 km stretch of the upper San Marcos River. All existing stands of *Z. texana* are located upriver of this area, and very few other native species are present within the affected reaches. However, the explosive increase in *C. beckettii* observed to date indicates that the situation is likely to quickly become much more difficult to control.

Should control actions be considered, a holistic, ecosystem-based approach should be utilized. Control plans that focus on a single alien species without addressing the underlying disturbance phenomena that permitted the successful invasion, deal only with the effect of environmental degradation and not the causes (Edwards 1998). Single species approaches may simply delay an inevitable permanent establishment of the alien in the region or simply trade one invasive species for another equally damaging one (Hobbs and Humphries 1995). In the San Marcos River, *C. beckettii* has invaded a portion of the river that was virtually empty of aquatic vegetation. Given the apparent suitability of this species for this particular area and the apparent popularity of the species within the aquarium trade (illustrated by the large number of sites on the World Wide Web devoted to this genus), the likelihood of re-introduction is high. At a minimum, eradication efforts should be followed by an aggressive restoration effort to fill the "empty niche" with more desirable, native vegetation such as *Zizania texana* and *Vallisneria americana*.



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